Porous Cement Pavement(Material)with High Reflectance and Water Retention and Heat Resistance

Jianwei Fu[1], Peifu We[1], Bo Zhou[2], He Chen[2]
[1]Guizhou Provincial Highway Development Co., Ltd, Guiyang, 55000, China
[2]Changan University & the Second Highway Engineering Co., Ltd., China Communications Construction Co., Ltd. Xian, 710000, China

Abstract: In this paper, by theoretical analysis, laboratory tests and other means, based on water retention, heat resistance and high reflection technology integration.To develop high reflectance water retaining and thermal resistant cement concrete(HWTCC), which can alleviate urban heat island effect ,water retaining materials including cement, silicon fume and fly ash were poured into thermal resistant porous cement concrete, which adopted high aluminum refractory gravel as aggregate. Its temperature reduction effect was validated, and compressive strength and flexural strength were tested as well. The results showed the compressive strength of HWTCC at 28d and 90d were 30.4Mpa and 42.1Mpa respectively, flexural strength at 28d and 90d were 4.6Mpa and 6.1Mpa. It was contrastively lower than porous cement concrete and water retaining cement concrete(WCC) with common gravel, but still met the requirement of heavy traffic pavement design of China. Compared with SMA, PCC, WCC, the highest temperature of WTCC decreased by 11.4℃,5.5℃ and 4.1℃ on the surface, and 10.3℃,6.1℃ and 4.6℃ in the inner part, respectively.the highest temperature of HWTCC decreased by 16.4℃,8.7℃and 6.6℃ on the surface, and 15.5℃,9.1℃ and 7.2℃ in the inner part, respectively.

Keywords: Heat island effect; Temperature; Water retention; Thermal resistance; Temperature reduction

1. Introduction

1.1. Domestic and foreign research status

With the continuous expansion of the city scale and the development of transportation, there are more and more artificial underlays for roads, plazas and houses in the city, and the proportion of natural underlying surfaces is becoming less and less. The artificial underlying surface cuts off the hydrothermal circulation channel of the natural underlying surface, and its heat absorption is good, and the near-surface air temperature is increased to form the Urban Heat Island (UHI). The urban heat island effect refers to the phenomenon that the temperature in the city is significantly higher than that in the peripheral suburbs. People who have lived in the central area of Jeju for a long time will be characterized by emotional irritability, lack of energy, depression, depression, memory loss, insomnia, recurrence of gastrointestinal diseases, etc., and endless troubles for the work and life of urban people. Therefore, the city The heat island effect has become an urgent problem to be solved in urban development. Road pavement is an important part of urban artificial underlay and contributes a lot to urban heat island effect. Therefore, research and development of new pavement to alleviate urban heat island effect has become an urgent problem for road science and technology workers [1].

In order to reduce the temperature of asphalt pavement and alleviate the urban heat island effect, researchers at home and abroad have conducted research on the cooling type pavement, mainly including road heat reflective coating, large pore pavement, water retaining pavement and heat resistant pavement materials.

1.1.1. Road heat reflective coating

In 2002, Japan developed a coating that can reduce the temperature of the asphalt pavement, which can reduce the road surface temperature by 15 ℃, but its cost is high, reaching 300-400 yuan / m 2 [2]. Later, Harbin Institute of Technology developed a heat-reflective coating for road surface cooling, and the surface temperature of the test piece was 8.3 to 12.8 ℃ [3]. The disadvantages of the road heat reflective coating are: poor anti-sliding performance, road surface reflection affecting night driving, and high cost.

1.1.2. Large pore pavement

The macroporous asphalt mixture is an open-graded asphalt mixture with interconnected voids and a void ratio of about 20%. It has been widely used abroad for its remarkable water permeability, noise reduction and good anti-sliding properties. In China, Song Xianfa et al [4-5] showed that the drainage asphalt pavement has a good effect on reducing the temperature of the middle and lower layers. Compared with the SMA pavement, the cooling of the large pore pavement is 2.5 ℃.

1.1.3. Water retaining pavement

As early as the 1990s, Japan began research on low-heat-absorbing and water-retaining paving. In 1994, it developed a water-retaining interlocking block paving. In 1998, it successfully developed an asphalt mixture-type paving system. Paving [6]. In China, Hu Liqun et al [7] filled the water-absorbing materials such as fly ash and blast furnace slag into the macroporous mixture, and the maximum temperature drop of the road surface was above 10 ℃.

1.1.4. Heat-resistant pavement material

The heat-resistant pavement material is a pavement material proposed by domestic road workers to solve the road rutting disease and the urban heat island effect. Sha Aimin et al. [8] incorporated the calcined aluminum ore stone into the asphalt mixture, which can reduce the road surface temperature by about 5 ℃.

1.2. Commentary

In order to reduce the temperature of the road surface, the simplest method is to spray water, but the water spray not only consumes a lot of water resources, mechanical equipment and personnel, but also reduces the anti-slip performance of the road surface and increases the safety hazard. The road surface heat reflective coating has poor anti-sliding performance, and the road surface reflection affects night driving, and the cost is high. The cooling rate of the large pore asphalt pavement is small. The heat-resisting road surface has a good cooling range and can guarantee the road performance to a certain extent.

In this paper, through theoretical analysis, laboratory tests and other means of high-reflection water-retaining and heat-resistant porous cement pavement research, comprehensive heat-resistance, water retention and high-reflection three cooling techniques, the development of a new type of high-reflection water-resistance that can alleviate the urban heat island effect Hot porous cement pavement. Not only can the cooling effect be greatly improved, but also the potential risk of excessive degradation of road material performance due to a single technology.

2. Cooling Mechanism of High Reflection Water and Heat Resistant Road Surface

2.1. Resistance mechanism analysis

The high-reflection water-blocking and heat-resistant porous cement pavement integrates three kinds of cooling technologies of heat resistance, water retention and high reflection to realize composite cooling.

The lower the thermal conductivity of the material, the harder it is to transfer heat to the interior of the road, which in turn reduces the road surface temperature.

The high-alumina refractory gravel is used as the aggregate to arrange the porous heat-resistant cement concrete. Since the thermal conductivity of the high-aluminum refractory gravel is lower than that of the ordinary aggregate, the thermal conductivity of the cement concrete is lowered. The construction of a low thermal conductivity heat-resistant cement concrete on a road surface is equivalent to paving a layer of thermal insulation to prevent solar radiation from being transmitted downwards through the road surface, thereby reducing the road surface temperature.

2.2. Water retention mechanism analysis

The water retaining material consists of fly ash, cement, silica fume and water. Fly ash is a kind of porous material, which has strong water absorption and water retention. It is the reason for water retention of water retention materials and also plays a role in lubrication. In addition to the function of retaining water, silica fume can also act as a lubricant to improve the fluidity of the water retaining material. The hydrate formed after the cement is hydrated can provide strength and prevent the loss of the water retaining material.

The water-retaining material is poured into the porous cement concrete, and the water-retaining material in the water-retaining surface of the water-retaining material with high water absorption rate can absorb and preserve the water sprinkled on the road surface during the rain or high temperature season. The use of these preserved water vaporization at the time of evaporation reduces the road surface temperature.

2.3. High reflection mechanism analysis

The asphalt pavement belongs to the black pavement and has high heat absorption. The cement concrete pavement has good light reflection characteristics for the gray itself. The surface of the pavement is coated with a reflective coating composed of epoxy resin, curing agent, titanium dioxide and carbon black. , reflecting visible light in solar radiation, reducing the surface temperature of the road.

3. Strength Performance and Cooling Characteristics of High Reflection Water and Heat Resistant Road Surface

3.1. Strength performance

According to the method of (JTG E30-2005), four cubic test pieces of 15*15*15cm, SMA-13 asphalt mixture, ordinary cement concrete, water-retaining cement concrete, water-retaining and heat-resistant cement concrete (two pieces) were formed. The compressive strengths of 28d and 90d were tested; a rectangular specimen of 15*15*550 cm was formed and the bending strength of 28d and 90d was tested. Figure 3 and Figure 4 show the compressive strength and flexural strength results of porous cement concrete, water-retaining cement concrete and water-retaining heat-resistant cement concrete. It can be seen from the results that the compressive strength of water- and heat-resistant cement concrete 28 and 90d can reach 30.4 and 42.1 MPa, and the flexural strengths of 28 and 90d are 4.6 and 6.1 MPa, respectively, which meets the JTG D40-2011 specification. After the water-retaining material is poured, the strength of the cement concrete is enhanced, and the increase in compressive strength and flexural strength is between 1.4-2.9% and 4.4-4.9%, respectively, because the water-retaining material is filled in the void after hardening. Additional strength; when the cement dosage is the same, the compressive strength and flexural strength of the water-retaining and heat-resistant cement concrete are 5.6-10.1% and 8.3-10.3% lower than that of the water-retaining cement concrete, because the strength ratio of the high-alumina refractory gravel The basalt is low.

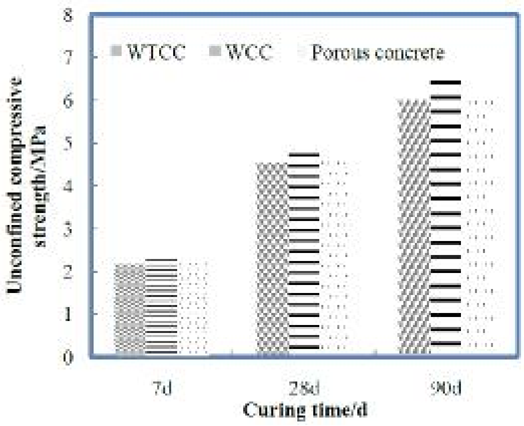

Figure 1. Compressive strength test chart

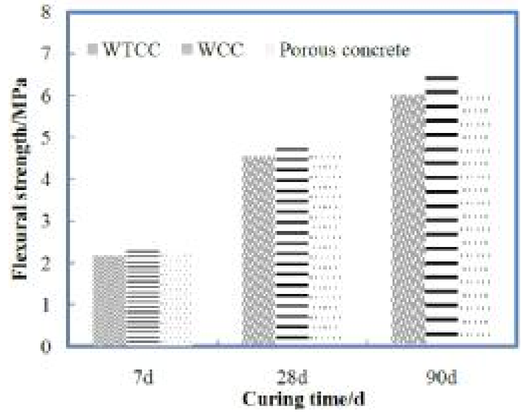

Figure 2. Bending strength test chart

3.2 Cooling characteristics

The temperature sensor was laterally implanted in the test piece, and the temperature was tested by the ZDR-41 multi-channel temperature automatic recorder of Hangzhou Zeda Instrument Co., Ltd. with an accuracy of 0.5℃ and a test frequency of 10 min. Before the test, the same kind of water was sprayed on the four kinds of pavements, and the process of one rainfall was simulated, and then the temperature recorder was connected to record the temperature curves of the four kinds of pavements.

The highest temperature, the lowest temperature, the average temperature of the whole day, the average daytime temperature (7:00 to 19:00) and the nighttime average. The temperatures are shown in Tables 2 and 3. It can be seen from the results that compared with SMA asphalt mixture, ordinary cement concrete and water-retaining cement concrete, the maximum temperature of the road surface of the designed composite cooling concrete is reduced by 11.4 ℃, 5.5 ℃ and 4.1 ℃, respectively, and the maximum internal pressure of the pavement is reduced by 10.3 ℃, 6.1 ℃ and 4.6 ℃.

At the same time, a water-retaining and heat-resistant cement concrete test piece was coated with a high-reflection layer, and the same test was carried out to obtain a temperature curve (Fig. 5, Fig. 6). The results showed that the highest temperature of the road surface was compared with the water-resistant and heat-resistant concrete test piece. By 5℃ lower, the interior of the road is reduced by a maximum of 5.2 ℃.

Table 1. Characteristic temperature of the road surface

Mixtures	Maximum temperature / ℃	Minimum temperature / ℃	All day average temperature / ℃	Average daytime temperature /℃	Night average temperature / ℃
SMA	62.9	17.2	35.3	43.8	25.0
PCC	57.0	15.3	32.4	40.0	23.5
WCC	55.6	14.4	31.1	38.0	23.2
WTCC	51.5	13.9	29.2	36.3	20.9
HWTCC	46.5	12.5	26.4	34.6	17.2

Table 2. Characteristic temperature at a depth of 5 cm

Mixtures	Maximum temperature / ℃	Minimum temperature / ℃	All day average temperature / ℃	Average daytime temperature /℃	Night average temperature / ℃
SMA	56.5	17.9	34.1	40.2	26.9
PCC	52.3	15.2	30.6	36.0	24.4
WCC	50.8	14.8	30.1	34.9	24.8
WTCC	46.2	14.7	27.7	32.2	22.6
HWTCC	41.0	14.3	24.5	30.1	20.4

In addition to the solar radiation intensity, the factors affecting the road surface temperature are related to the heat absorption of the road surface, the evaporation effect inside the road surface, and the thermal conductivity of the material. Further analysis of the four road surface temperatures and internal temperatures shows that:

First, as a black asphalt pavement, it has the highest heat absorption and the lowest reflectivity, and the solar energy radiated to the road surface is more absorbed into the road surface, thus having the highest temperature;

Second, the maximum temperature of the road surface of the water-retaining cement concrete and the depth of 5cm is 1.4℃ and 1.5℃ lower than that of ordinary cement concrete. This is because when the temperature rises, the moisture in the water-retaining material continuously evaporates and absorbs heat, making the road surface The temperature is lowered; as the water evaporation is completed, the cooling effect of the water retaining material is invalid, and the heat absorption of the fly ash and the silica fume in the water retaining material is higher than that of the cement, so the temperature of the water retaining cement concrete after 18:00 is higher than that of the ordinary cement. Concrete

Third, compared with the water-retaining cement concrete, the maximum temperature of the road surface is reduced by 4.1 ℃, and the maximum temperature at the depth of 5 cm is reduced by 4.6 ℃. This is because the water-retaining heat-resistant cement concrete is used high. Aluminum refractory gravel, which has a very low thermal conductivity and reduces the heat transfer from the road surface to the inside of the road surface. This is equivalent to covering a layer of temperature barrier on the road surface.

Fourth, the highly reflective coating makes the water-retaining and heat-resistant concrete pavement better in cooling effect, because the reflective coating can reflect a large part of the solar radiation radiated to the road surface, so that the road surface temperature is lowered.

4. Research Conclusions

The design method of water-retaining materials was proposed. Water-retaining materials with water retention capacity, fluidity and strength were all prepared by using cement, fly ash, silica fume and water.

A design method of porous cement concrete was proposed. High-strength and high-aluminum macadam and ordinary gravel porous cement concrete with high strength and void ratio of about 20% were prepared by using cement and 4.75-9.5mm aggregate.

The compressive strength of water- and heat-resistant cement concrete 28 and 90d can reach 30.4 and 42.1MPa, and the flexural strengths of 28 and 90d are 4.6 and 6.1MPa, respectively. Compared with ordinary cemented concrete and water-retaining concrete, it still meets the requirements. The design requirements of heavy traffic road pavement; compared with SMA asphalt mixture, ordinary cement concrete, water-retaining cement concrete, the designed maximum temperature of the composite cooling concrete pavement is reduced by 16.4 ℃, 8.7℃ and 6.6 ℃, respectively. Reduced by 15.5 ℃, 9.1 ℃ and 7.2 ℃.

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